Chapter 6
Momentum

Feb-10-10

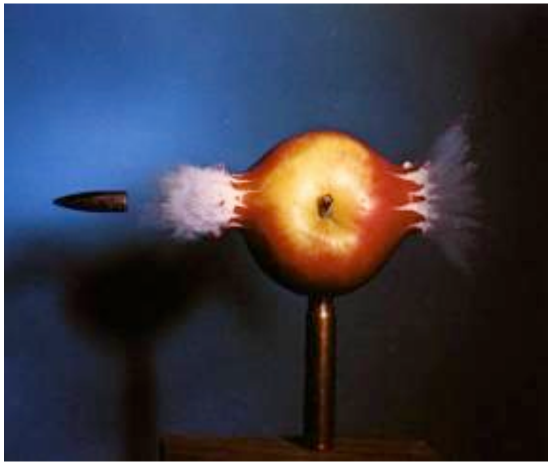
Force, Momentum, Energy

With Newton's Laws, we can understand motion just using forces.

It's easier to understand motion by introducing concepts of momentum and energy.

Momentum
Section 6-1

- Momentum of an object is can be thought of as “inertia in motion.”
- (Momentum) = (Mass) X (Velocity)
- $\mathbf{p} = m\,\mathbf{v}$
- Examples of objects with large momentums are supertanker (large mass) and bullet (large velocity).
- Aren’t momentum and inertia the same thing?
- The difference is if an object is at rest, it has no momentum, but it does have inertia.
- Momentum is a **vector** quantity. Direction matters!



Momentum
Units!

- Since momentum is found by multiplying mass and velocity, the units are…
- kg m/s
- There’s no fancy name for these units. Just say kilogram meters per second.

Example

A 2 ton car, going 60 m.p.h. hits a 5 ton truck, going 20 m.p.h..

Which vehicle, the car or the truck, has greater momentum?

The car because (2)x(60) = 120 and (5)x(20) = 100.

What would the car's speed have to be for the momentums to match?

Fifty m.p.h. since (2)x(50) = (5)X(20).

Aren't you forgetting something?

The direction of velocity.

How does that matter?

Rear-end crash not same as a head-on crash. More about this when we do collisions.

Momentum and Impulse
Section 6-2

- In Chapter 5, we learned to change the velocity of an object is to change its KE.
- If an object's KE is changed, work was done on the object.
- Work is F x d
- Therefore, changing the motion of an object can be described by **how hard** the push is and **how far** it's pushed for.
- The other way we can describe a change in motion is by **how hard** the push is and by **how much time** the push is applied for.
- We call F x t an **impulse**

Momentum and Impulse
Section 6-1 continued

To stop an object with a large momentum requires either:

- Large force (stopping the object quickly).
- Small force applied for a long time.

Notice that changing an object's momentum depends on force and time interval.

Impulse

Define impulse acting on an object as,

(Impulse) = (Force on object) X (Time interval)

$$I = F \quad t$$

Impulse & Momentum

An impulse causes a change in momentum

$$I = \Delta p = F\ t$$

Let's rearrange this formula.

$$F\ t = \Delta p$$

$$F\ t = \Delta m\ v$$

$$F\ t = m\ \Delta v$$

$$F\ t = m\ (v_f - v_i)$$

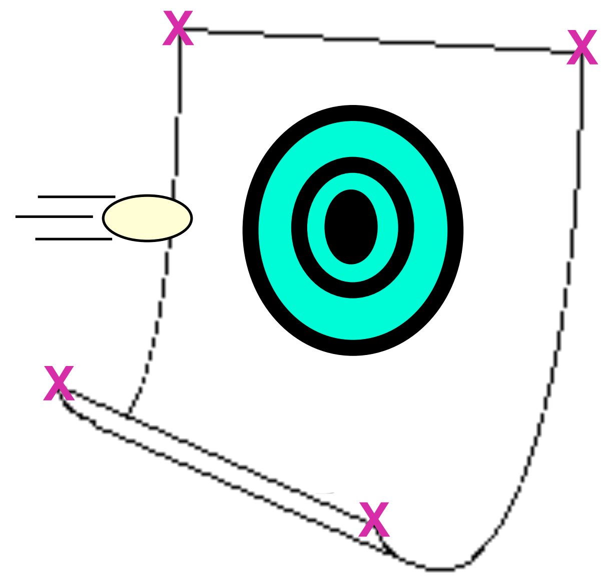
$$F = m\ \frac{(v_f - v_i)}{t}$$

$$F = m\ a$$

This relation comes from Newton's 2nd law.

Demo: Egg Throw

Throw a raw egg as fast as possible at a sheet that's held loosely.



X (Hold here)

Explanation

Throw egg at sheet or wall with same speed. Which case has:

Greater change of velocity?

Same in both cases.

Greater change of momentum?

Same in both cases.

Largest impulse on the egg?

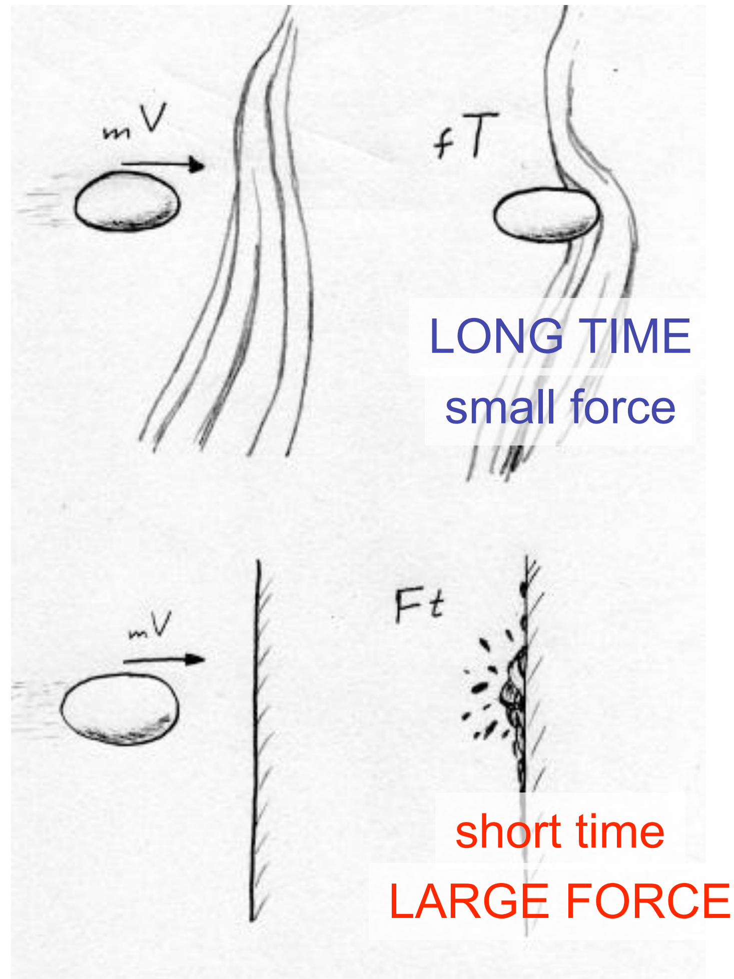
Same in both cases.

Largest time of impact?

Throw at the sheet.

Largest force on the egg?

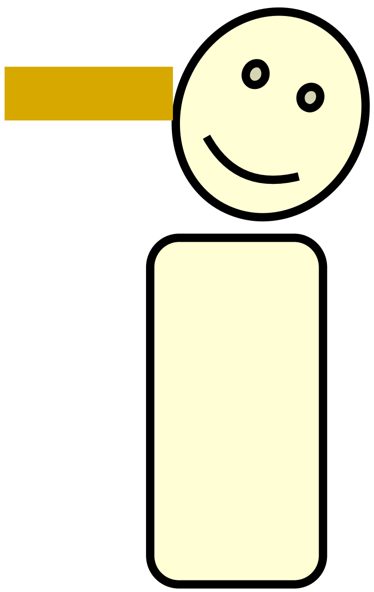
Throw at the wall.



Demo: Boxer taking punch

Safest when fast moving punch is strikes head over long period of time.

(force) x (TIME)



(FORCE) x (time)

Not safe if fist hits rigid body!

Check Yourself

A 2 ton car, going 60 m.p.h. hits a 5 ton truck, going 20 m.p.h..

The force of impact is greatest on which vehicle, the car or the truck?

Force on each is equal (by Newton's 3rd Law).

The impulse is greatest on which vehicle, the car or the truck?

Force equal & time of contact equal, so impulse equal.

Change of momentum greatest?

Equal for the two vehicles.

Change of velocity greatest?

For the car (less mass).

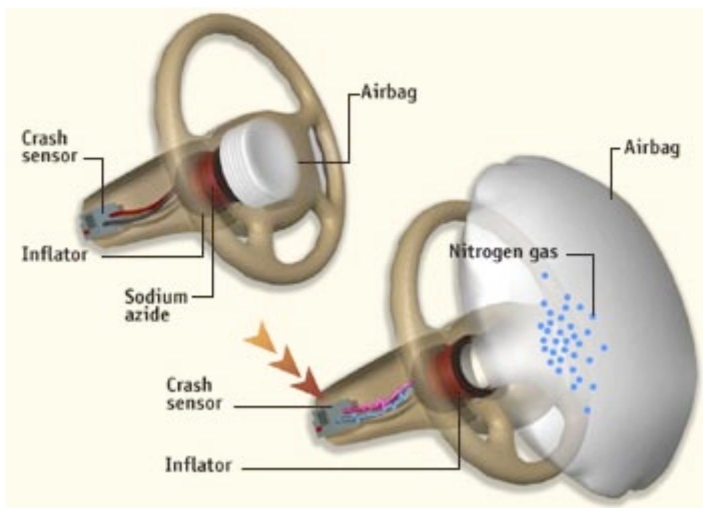
Driver injury greatest?

Depends on safety features.

Automobile Safety

Maximizing the time of impact *on the driver* minimizes the force of impact. This principle used in design of:

Seatbelts



Air Bags

Crumple Zones

Making impulse work for you

Q: When you want to give something a large momentum, and you can only apply a limited amount of force, what can you do?

A: Apply the force over a long period of time

By doing this you give it a larger impulse and therefore a larger change in momentum.

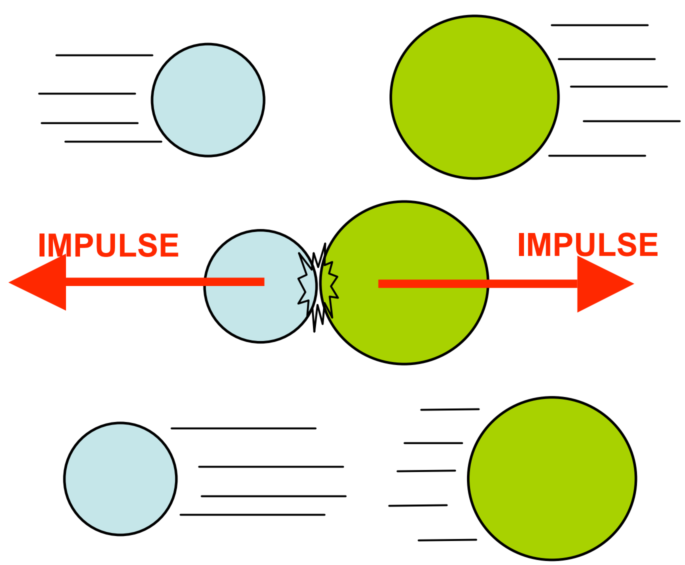
Ex) Cannons and rifles have a long barrel

Ex) In sports where you throw or hit things athletes are coached to “follow through.”

Ex) blow darts

Conservation of Momentum and Collisions
Section 6-2

When two objects collide, impulse is equal and opposite for the two objects.



Before collision

Impact

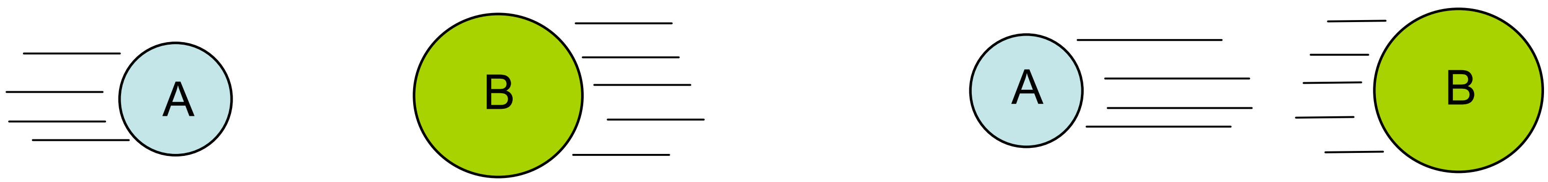
After collision

Each object has equal and opposite change in momentum.

Conservation of Momentum

Since change of momentum in a collision is equal and opposite, the momentum gained by one object is the amount lost by the other.

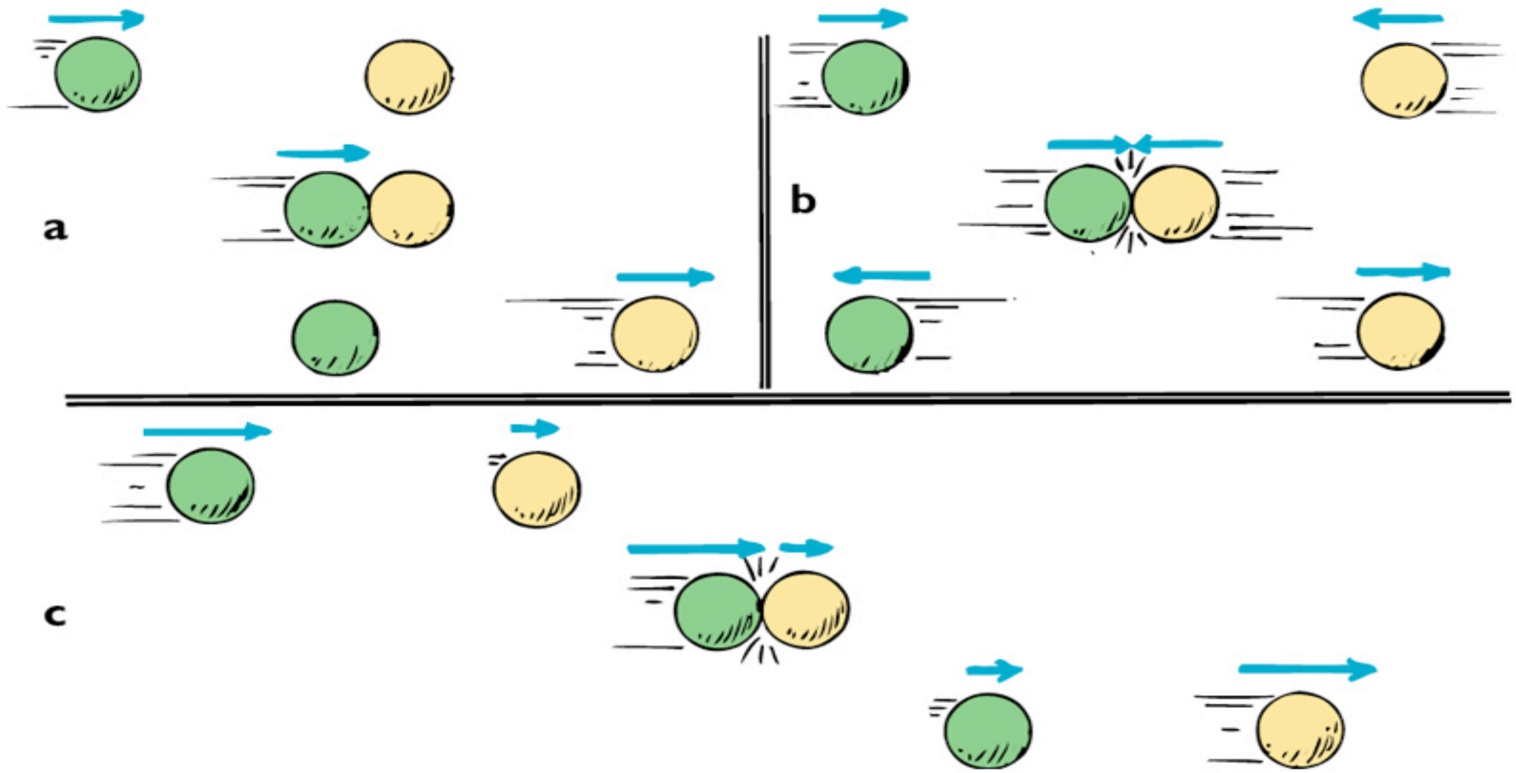
Momentum Object A Before Collision	+	Momentum Object B Before Collision	=	Momentum Object A *After* Collision	+	Momentum Object B *After* Collision



Actual amount of momentum exchanged depends on the details of the collision, such as whether or not collision is elastic.

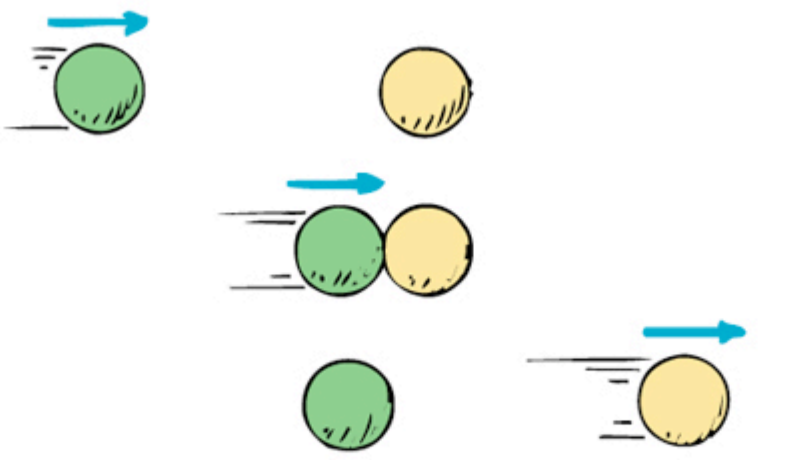
Demo: Elastic Collisions

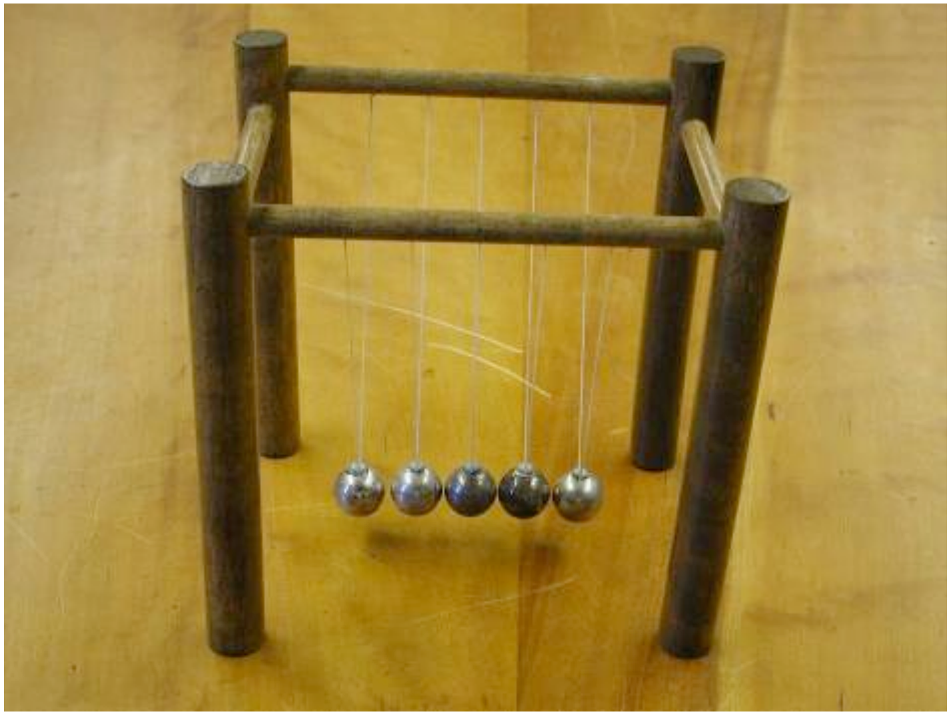
Objects of equal mass exchange momentum on elastic collisions. In rare cases, they also exchange all their KE as well.



Demo

Steel balls collide elastically, exchanging momentum on collision.





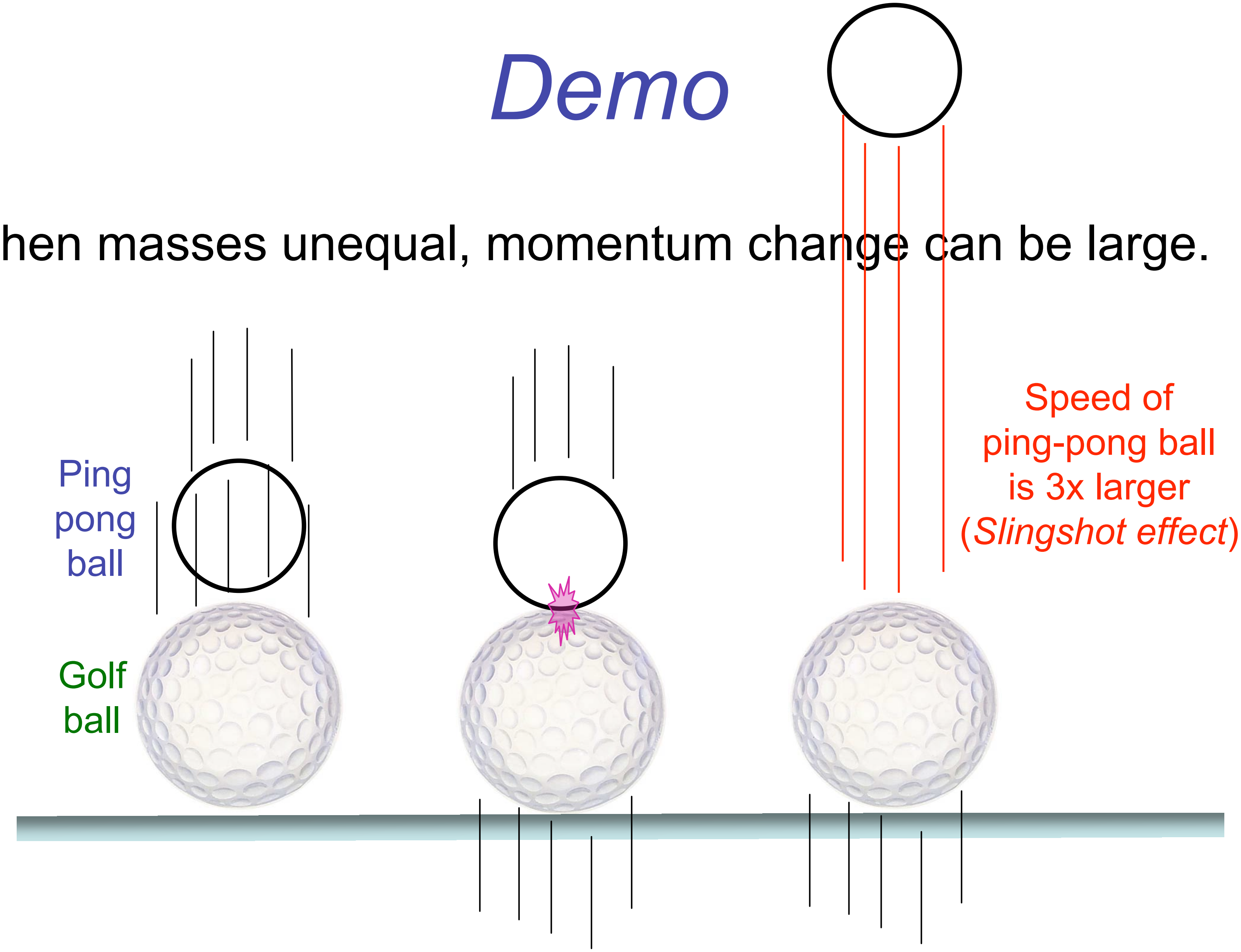
Demo: Don't Scratch

To sink a billiard ball that is very close to the pocket without having the cue ball go in as well ("scratching") strike the cue ball hard so it makes a crisp, elastic collision.

As with demo, cue ball will stop after giving all its momentum to the other ball in the collision.

Demo

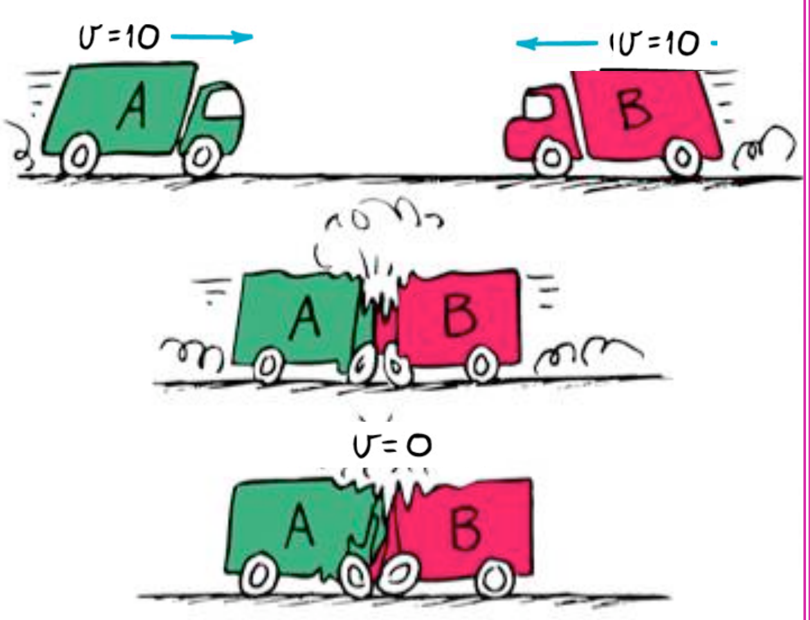
When masses unequal, momentum change can be large.

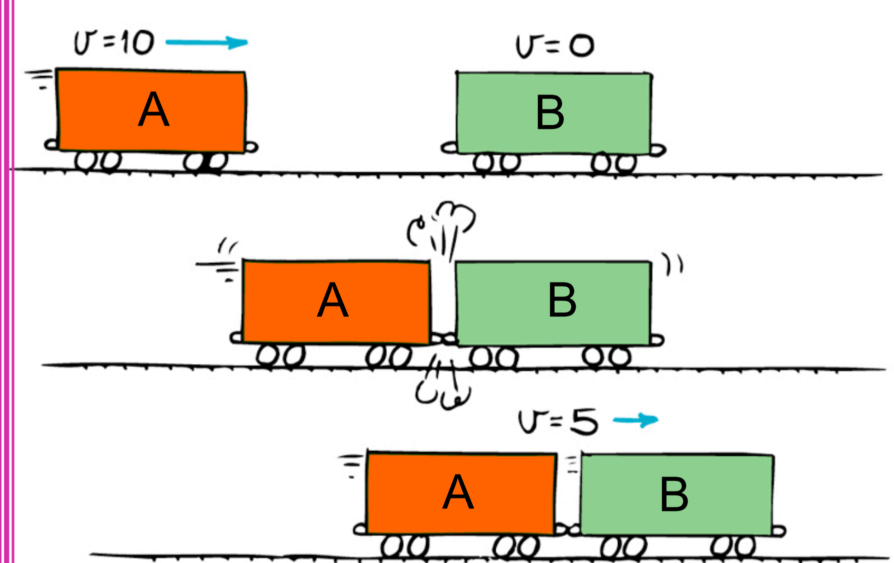


Demo: Perfectly Inelastic Collisions

Objects stick together after colliding.

KE is not conserved. Energy is lost to sound and changing the shape.

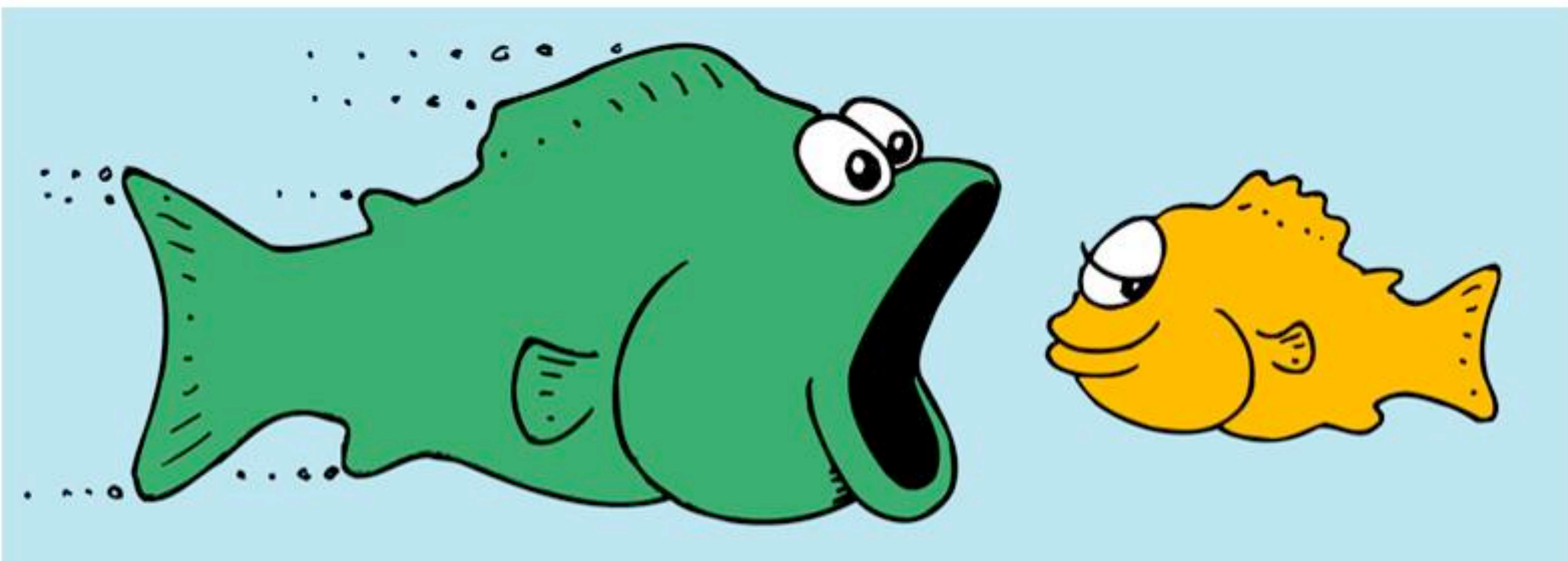




Check Yourself

Large (4 kg) fish swims at 3 m/s towards a small (2 kg) fish at rest and swallows it for lunch.

Total momentum before lunch?

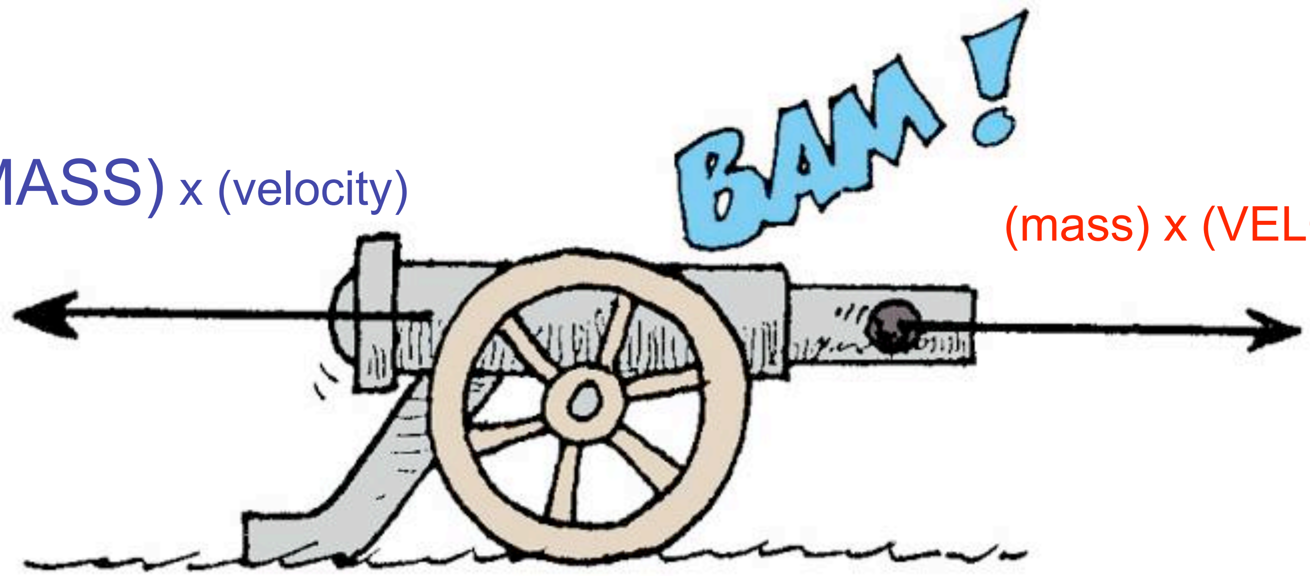


Recoil (explosion)

Momentum conservation also explains recoil

(MASS) x (velocity)

(mass) x (VELOCITY)



Recoil effect is like an inelastic collision in reverse.

Complicated Collisions

Collisions at an angle (not head-on) are more complicated. Learn by playing pool.